UNIVERSITÉ DE
SHERBROOKE

Cartel Centre d'applications et de recherches en télédétection

Retrieval of land surface temperature under snow and SWE using 10, 19, and 37 GHz brightness temperatures

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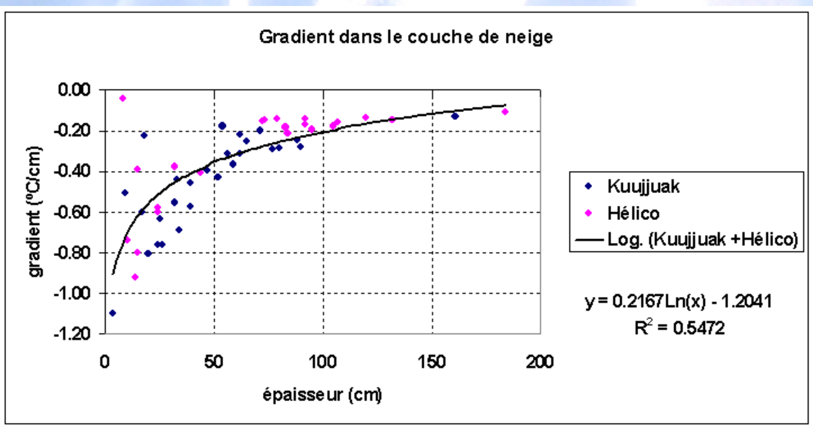
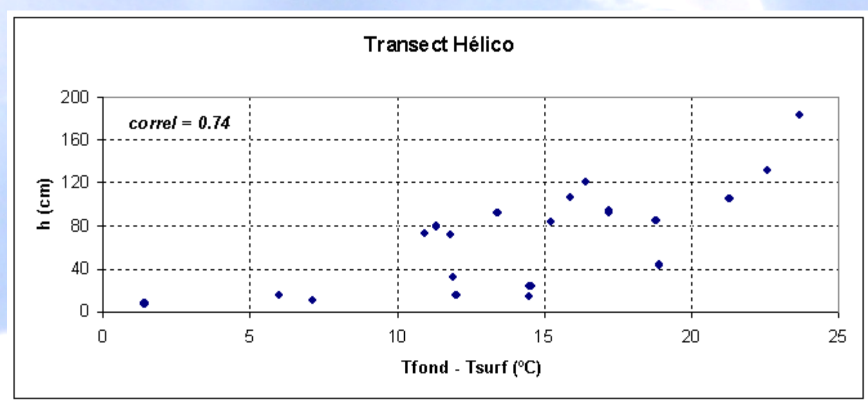
Difficult problem:
to separate soil, snow and air temperature

Snow cover has insulating properties (low thermal conductivity) causing great differences between air and snow/soil interface temperatures. The resulting temperature gradient is measurable.



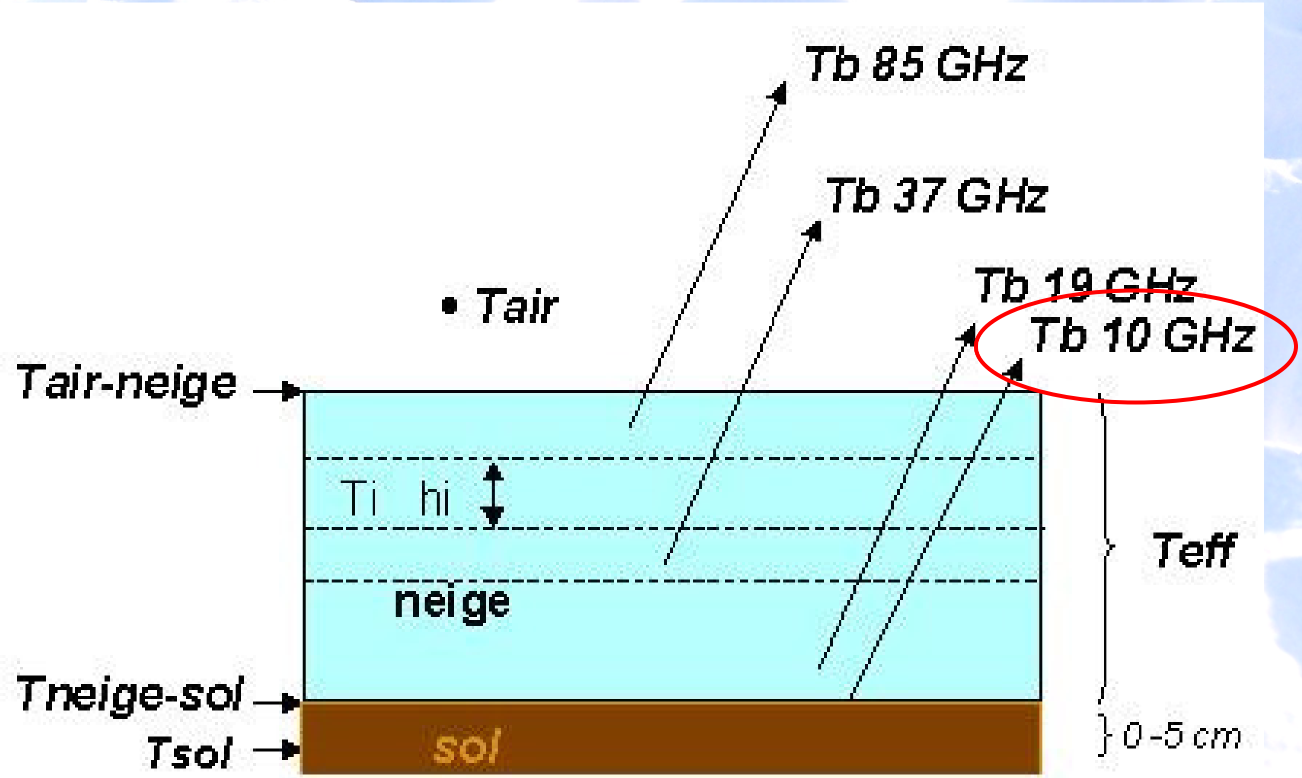
$$T_{gradient} = (T_{air/snow} - T_{soil/snow})/h_{snow}$$

The differences are highly variable spatially and temporally given snow and soil properties along with basic meteorological parameters



Difficult problem:
to separate soil, snow and air temperature

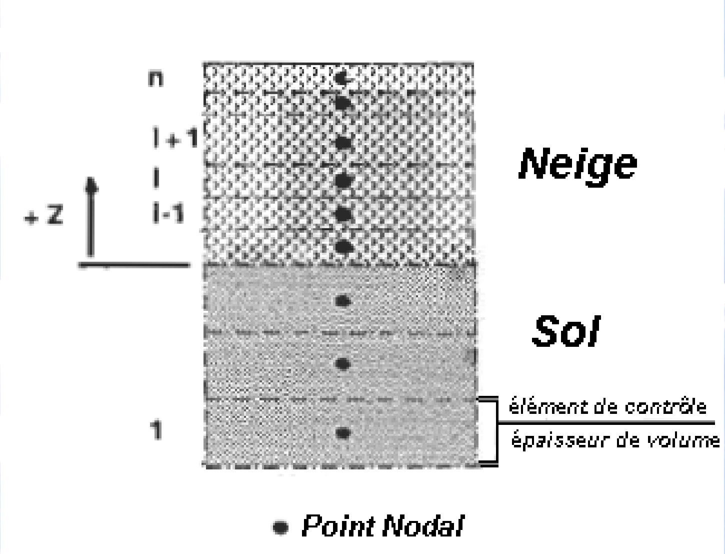
In presence of snow, many T_{bs} can be defined given their respective penetration depth:



Method

Model coupling: Snow/soil model with PMW emission model

In SnTherm, snow and soil layers and divided in 'control' volumes with associated geophysical properties.



Input parameters for SnTherm

- **Soil properties** (temperature, thickness, humidity, granulometry)
- **Meteorological data** (precipitations, precip. phase, air temperature, humidity, wind speed/direction, radiative budget)

Output

- **Vertical profile of snow:** temperature, thickness ,density, grain size, wetness.

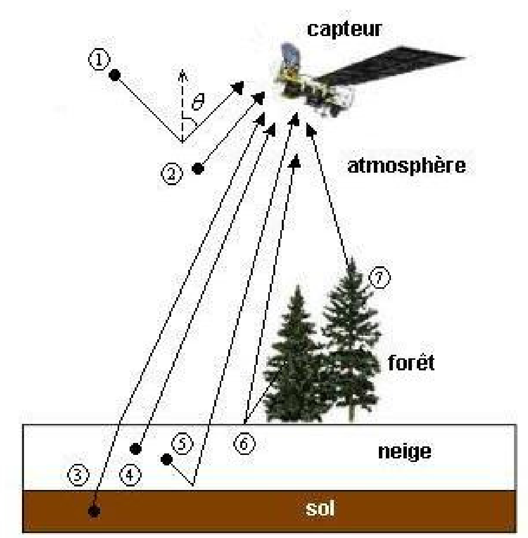
PMW emission model (HUT)

HUT model

Semi empirical model developed by the *Helsinki University of Technology* that simulates brightness temperatures from a given snow cover.

Input parameters for HUT

- **Snow properties-SnTherm** (thickness, density, grain size, temperature, wetness, salinity)
- **Soil properties-SnTherm** (temperature, roughness, humidity)
- **Vegetation** (stem volume, cover fraction, temperature)



Output

- Brightness temperature T_bV

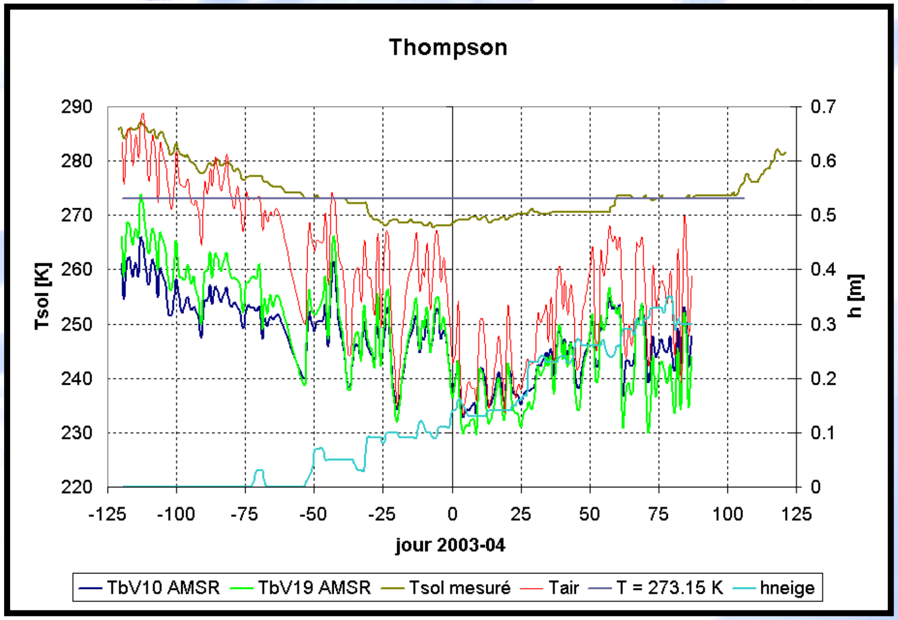
Satellite measurements of T_b

Temporal evolution of T_bV, T_{soil}, T_{air} and h_{snow}

Thompson station, Churchill, Manitoba

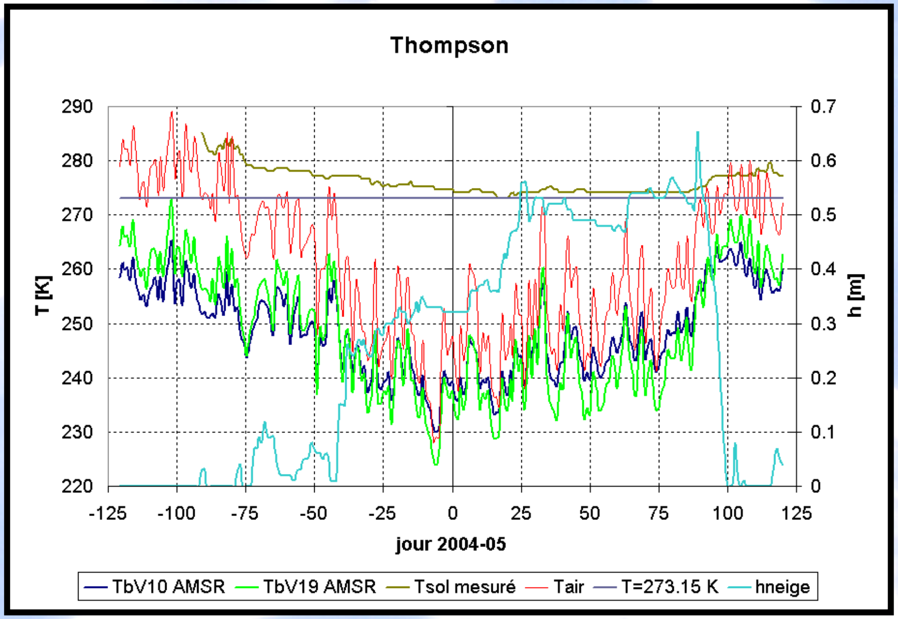
Frozen soil

2003-04



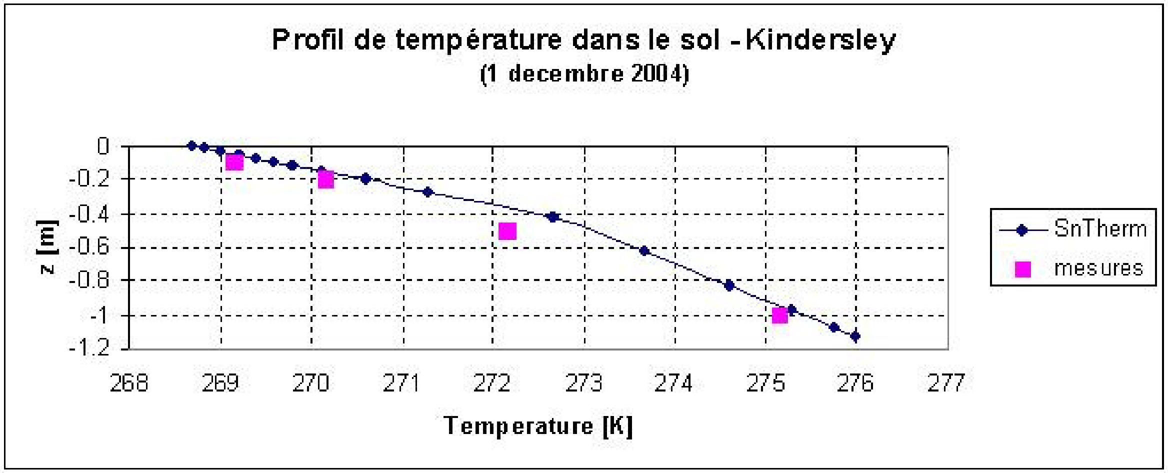
Unfrozen soil

2004-05

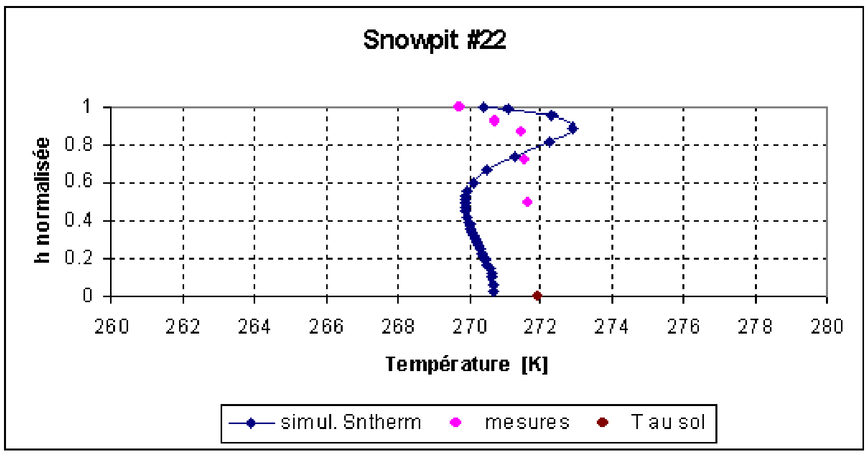


Results (T_{soil} from SnTherm)

Soil temperature profile at Kindersley station (measured and modeled):



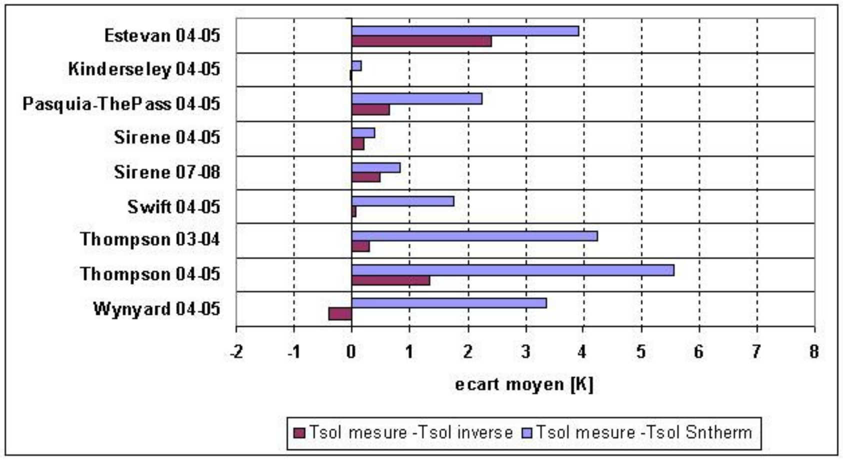
Snow temperature profile at SIRENE station (measured and modeled):



Teff (SnTherm)= 270.84 K
Teff (measured) = 271.41 K

Results (T_{soil} from inversion)

Average differences between predicted T_{soil} and predicted T_{soil}



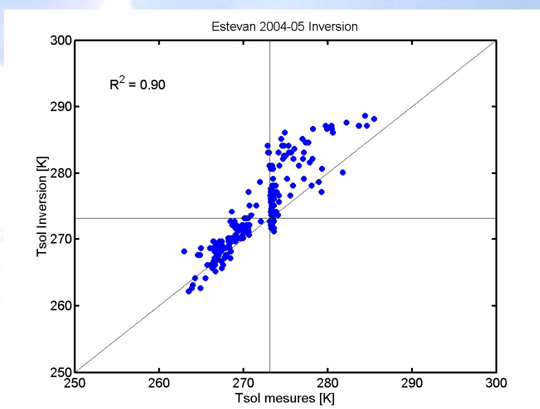
Frozen soil detection (i.e. < 0C) = 86%

Overall accuracy = 77%

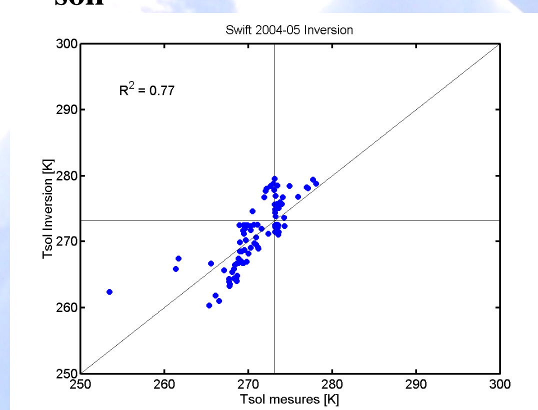
Inversion much better!!!

Inversion ➔ T_{soil} required so that T_b Hut = T_b AMSR-E

Correlation measured and inversion T_{soil}



Estevan station
R^2 =0.90



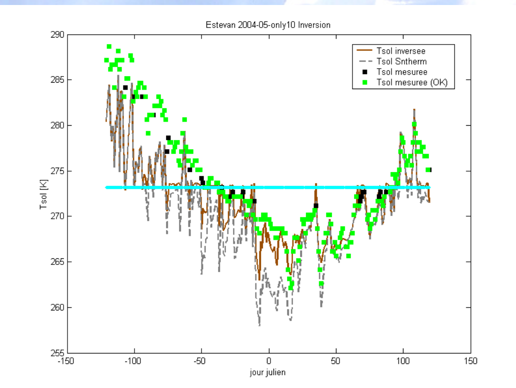
Swift station
R^2 =0.77

Results (T_{soil} from inversion)

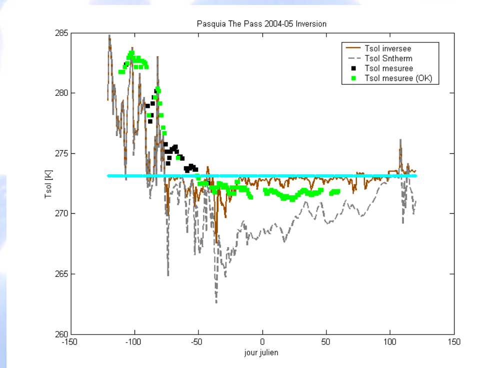
RMSE:
Tsoil(NARR) = 6.74 K
Tsoil(SnTherm) = 4.61 K
Tsoil(Inv._T_b) = 3.29 K

Temporal evolution of T_{soil}

Estevan

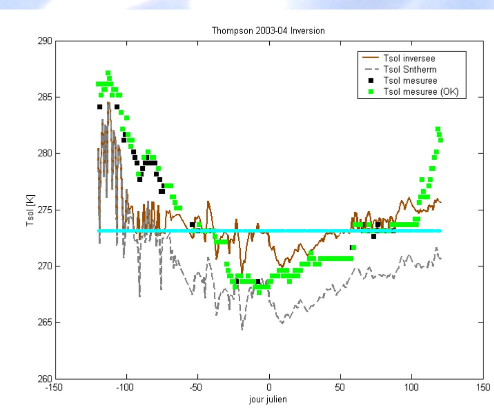


Pasquia

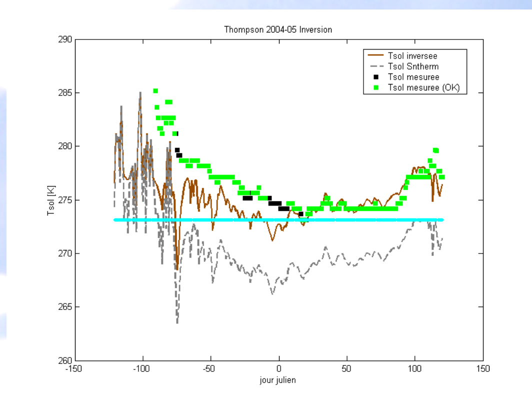


Thompson

2003-04



2004-05



Snow Water Equivalent analysis

Coupling CROCUS + MEMLS

1) Forward mode analysis : SIRENE experiment
2) Retrieval mode (EnKF): CLPX

SIRENE Experiment 2008

Assumptions:

Liquid precip if T>2°
Solid precip if T<0°

$$\Gamma_p = 1 - T_{bp}/T_{ground}$$

$$lc = \alpha\ (1 - \rho)\ D_{opt}$$

Results SIRENE Experiment 2007-2008

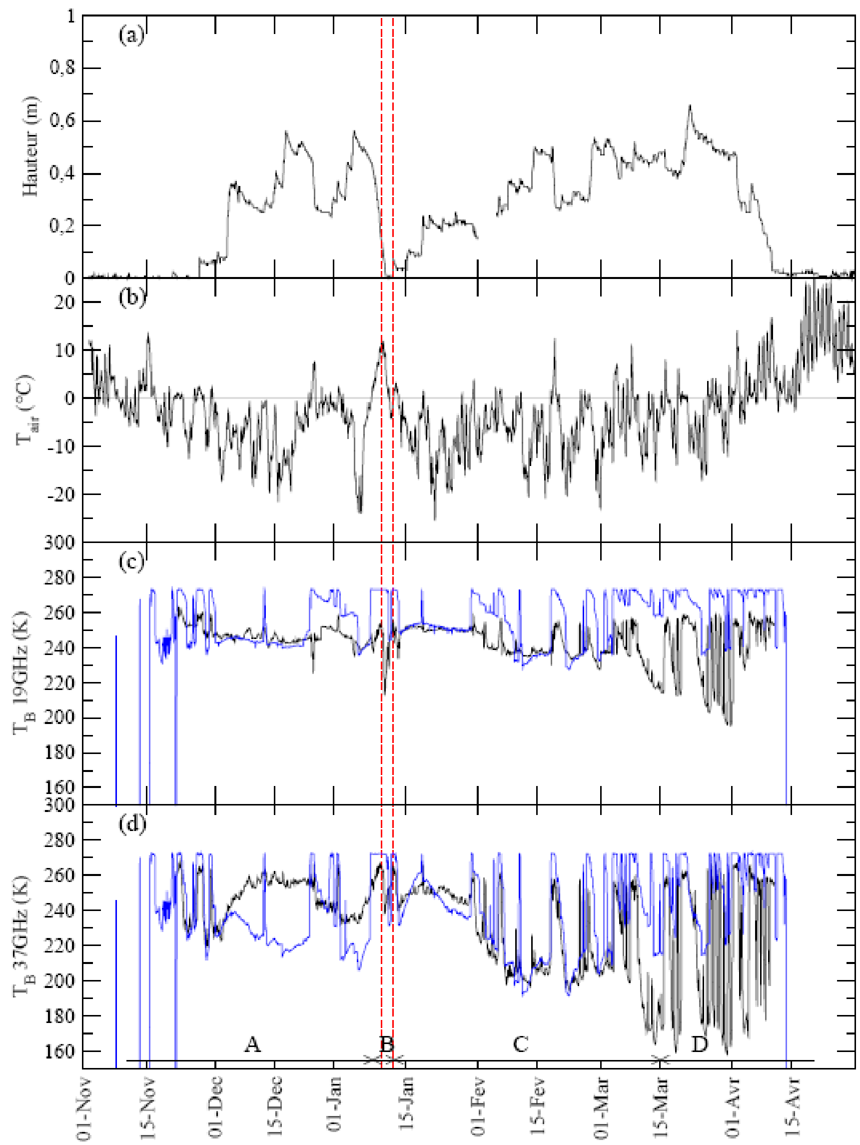
Better results for dry periods

RMSE 19V : 2.8 K

37V: 6.5 K

Tb(SBR)

Tb(CROCUS-MEMLS)



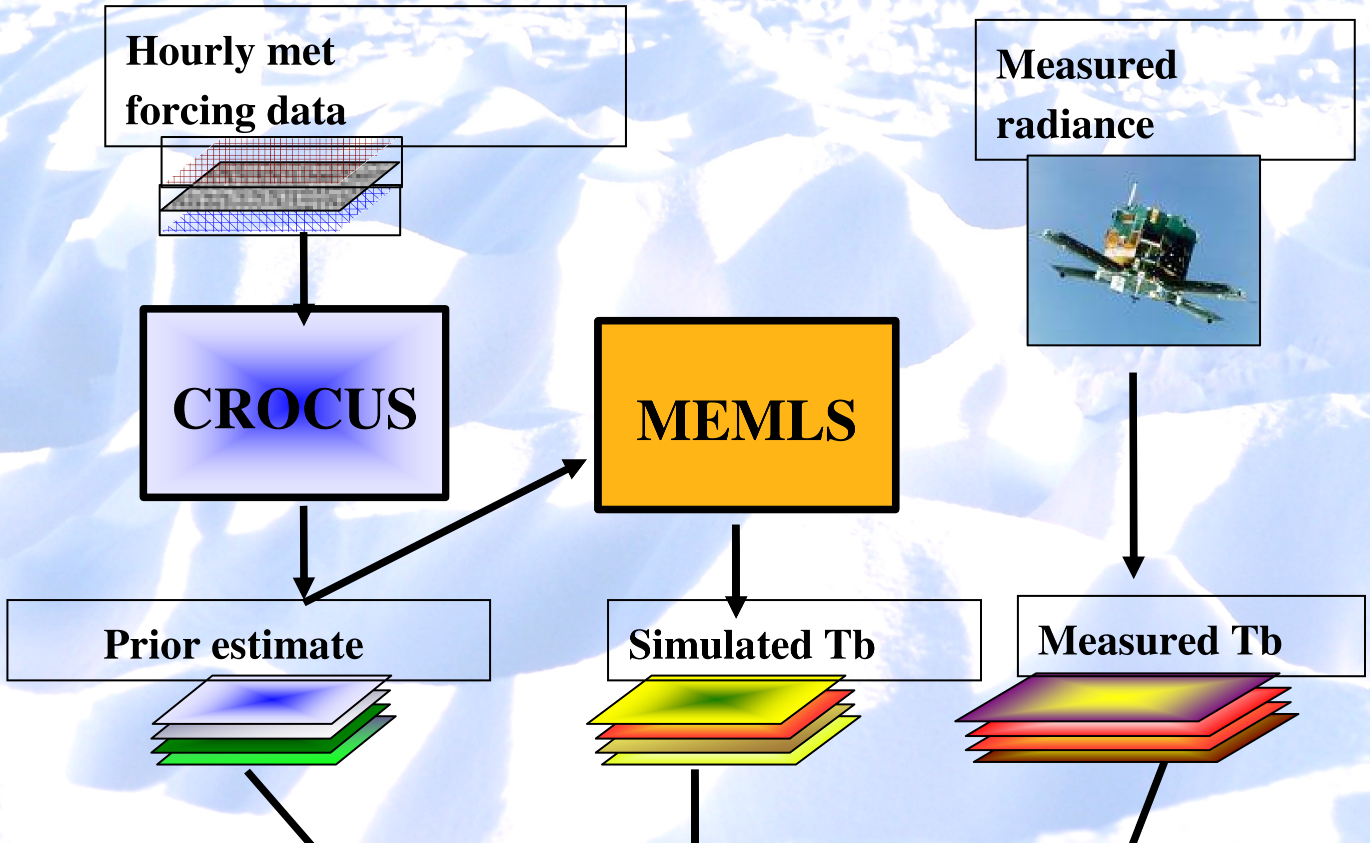
Strong influence of ground conditions (temp, wetness)

Metamorphism linked to melting episodes

SWE inversion

Snow water equivalent can be determined by using the ensemble Kalman Filter (EnKF) to assimilate Tb in a multi-layered snow physical model.

SWE inversion



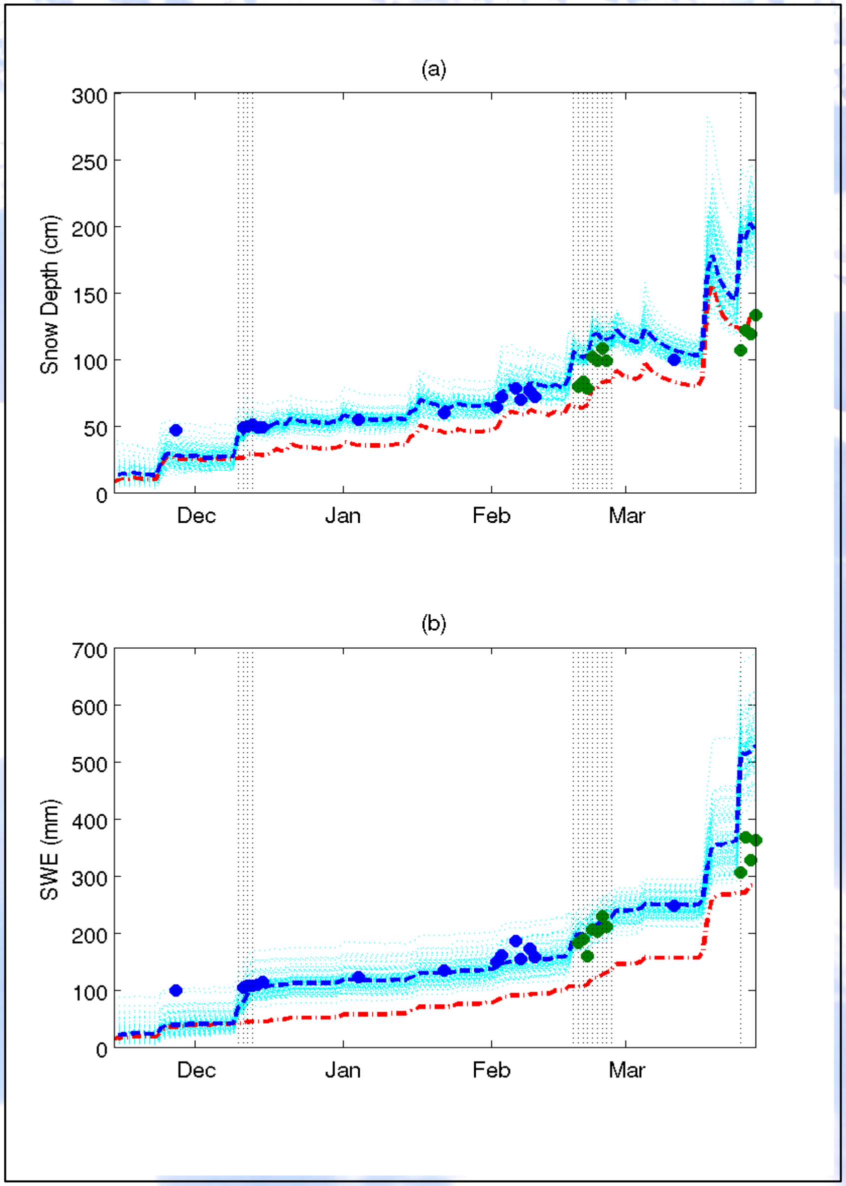
$$Y^a = Y^f - K[\, Tb_{simulated} - (Tb_{obs}+v)]$$

Results and discussion

GBMR-7's Tb assimilation

	open-loop		EnKF	
	Bias (cm)	Rmse (cm)	Bias (cm)	Rmse (cm)
Depth	3.87	16.7 (23%)	-8.1	11.6 (16.1%)
SWE	7.98	7.0 (44.3%)	1.40	1.49 (9.4%)

CLPX data



Conclusion

• We showed that radiance assimilation in a multi-layered snow physical model can be used to retrieve SWE.

• Results are encouraging but the system needs more testing.

- Detailed study of the CROCUS/MEMLS coupling is needed:

  - a) Ice layer density,
  - b) Snow density,
  - c) Grain size/Correlation length (IR methods).